Status of space charge simulations in the Main Injector for Project X using Synergia

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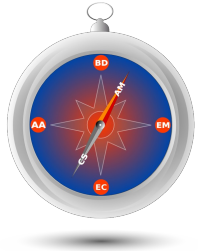
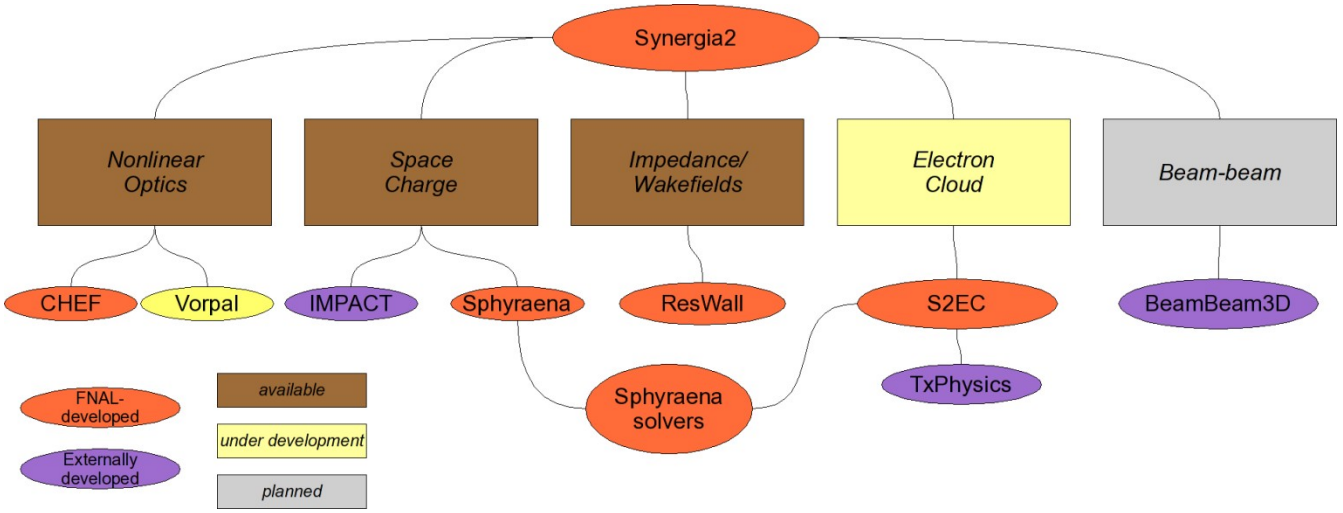
SciDAC
Scientific Discovery through Advanced Computing



Accelerator modeling tools development: Synergia



Beam Dynamics framework with fully 3D PIC capabilities

Utilizes both native and external physics modules/algorithms

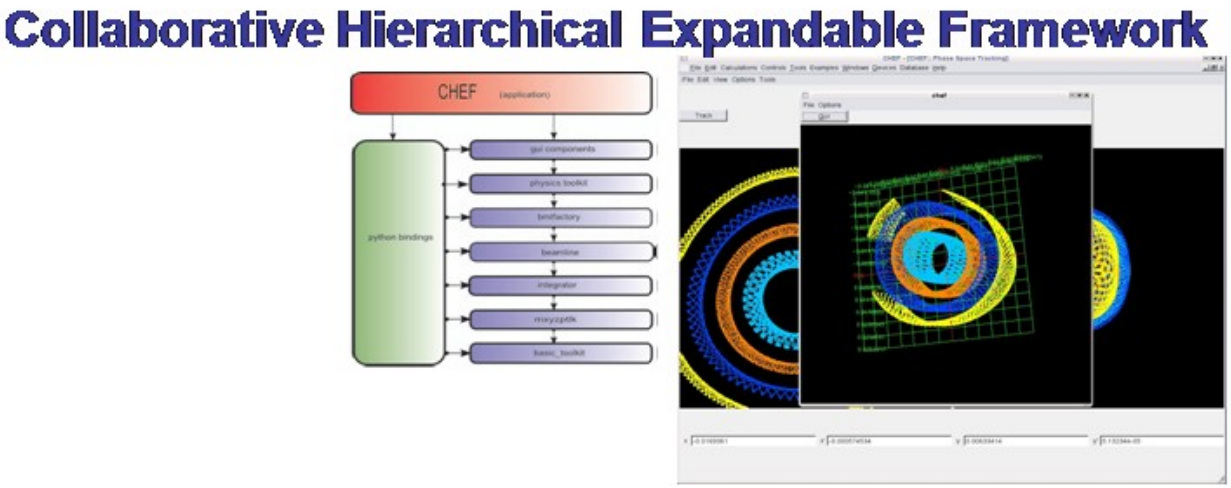
Includes space-charge & impedance (single and multi-bunch)

Single-particle physics from CHEF

Runs on desktops, clusters and supercomputers

Flexible framework allows for fully dynamic simulations including ramping, feedback, etc

Tools development, continued: CHEF



CHEF originally developed at Fermilab starting in the early 90's

Single-particle optics with full dynamics

Can be reduced to arbitrary-order maps

We have done demonstration calculations in Synergia to 15th order

Supports customizable propagators (fully extendable)

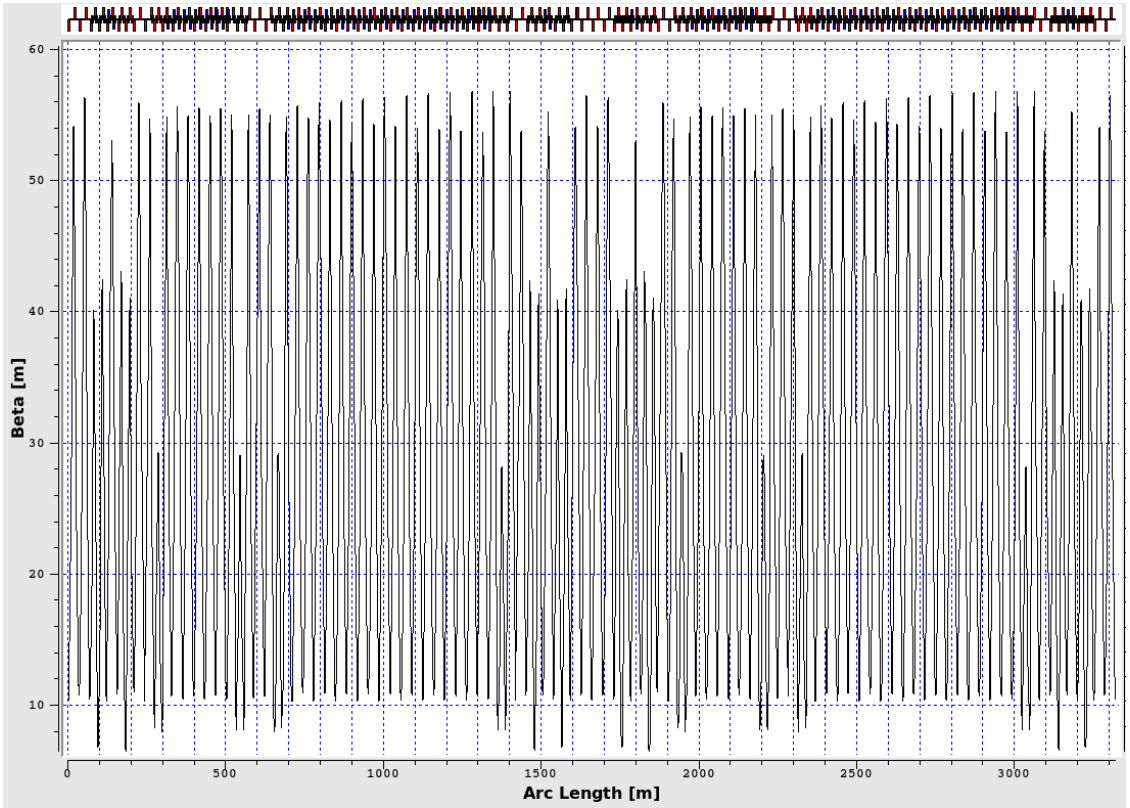
MAD and XSIF parsers

Internal representation not limited by MAD parameters

Starting points: the lattice

Lattice file mi20-mad-F

- 104 pairs of focussing-defocussing quadrupoles
- No H-V coupling to first order



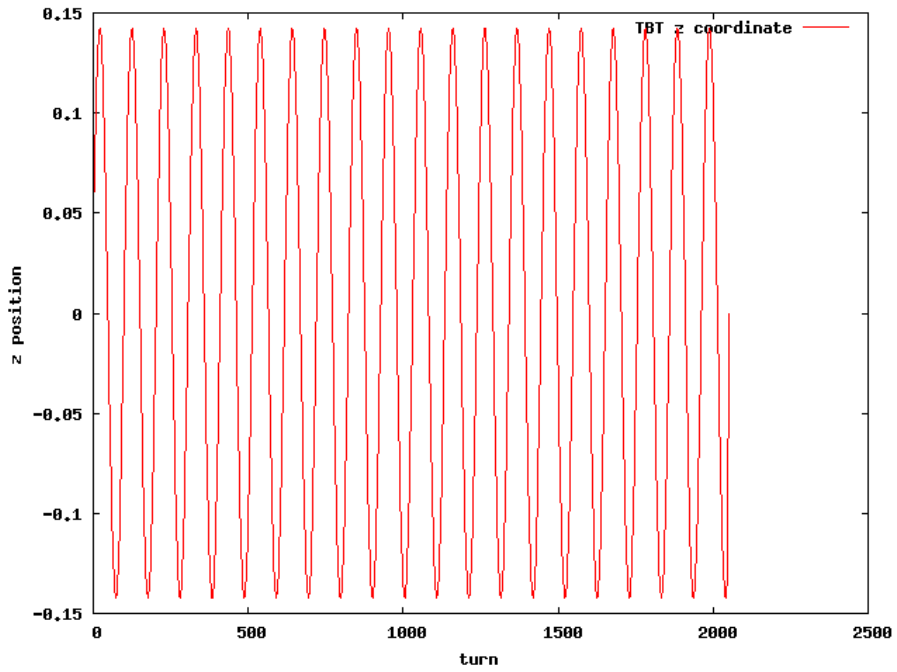
Qx = 0.42528 Qy = 0.41528

Tunes and beta functions agree with LBNL calculations

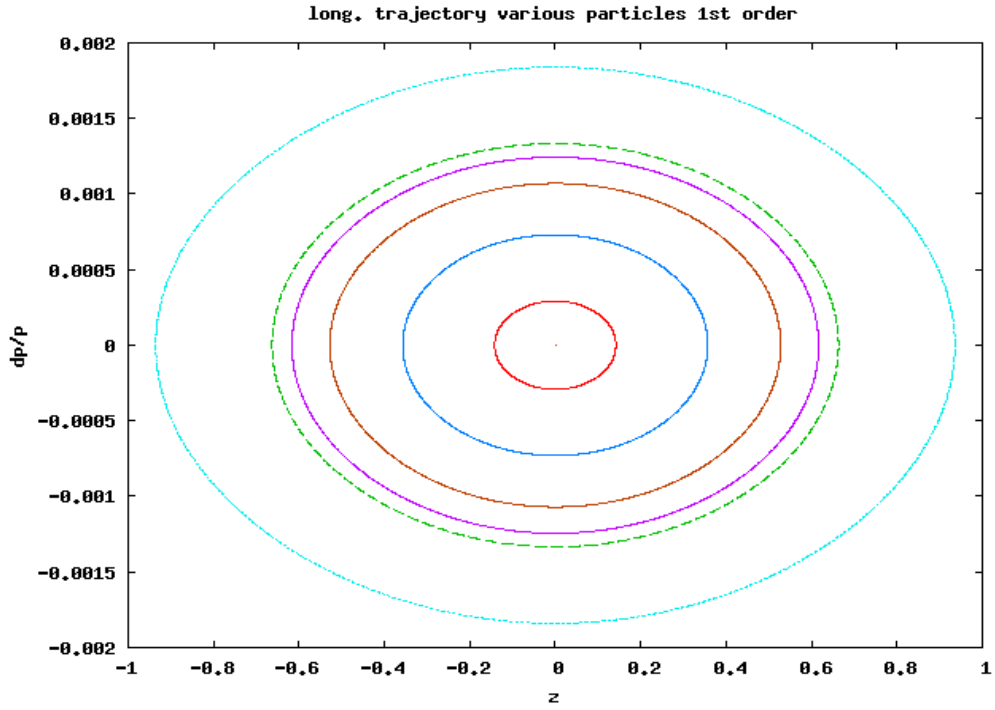
Starting points: longitudinal parameters

18 RF Cavities energized to total voltage of 1 MV

Synchrotron tune



Longitudinal phase space



19 oscillations in 1967 turns, Qs = .0096

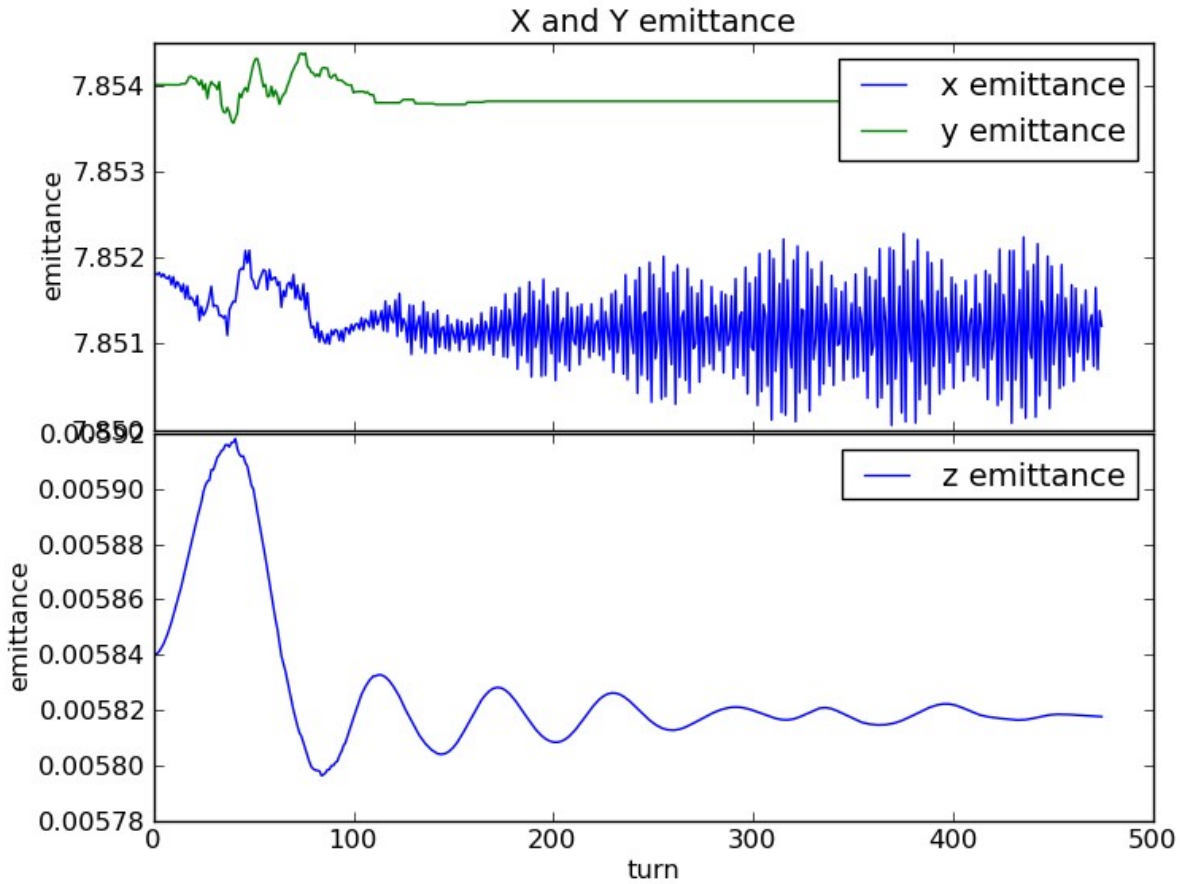
Starting points: initial particle distribution

- Initial distribution moments chosen to match LBNL distribution
- Particle distribution matched to lattice to first order

Parameter	LBNL	FNAL	rel diff
std(x)	0.00295	0.00294	-0.0034
std(x')	0.0003224	0.0003227	0.0009
std(y)	0.007013	0.007027	0.0020
std(y')	0.0003157	0.0003168	0.0035
std(z)	0.3096	0.3113	0.0055
std(dp/p)	0.0005977	0.0006367	0.0653

Emittance evolution with no space charge

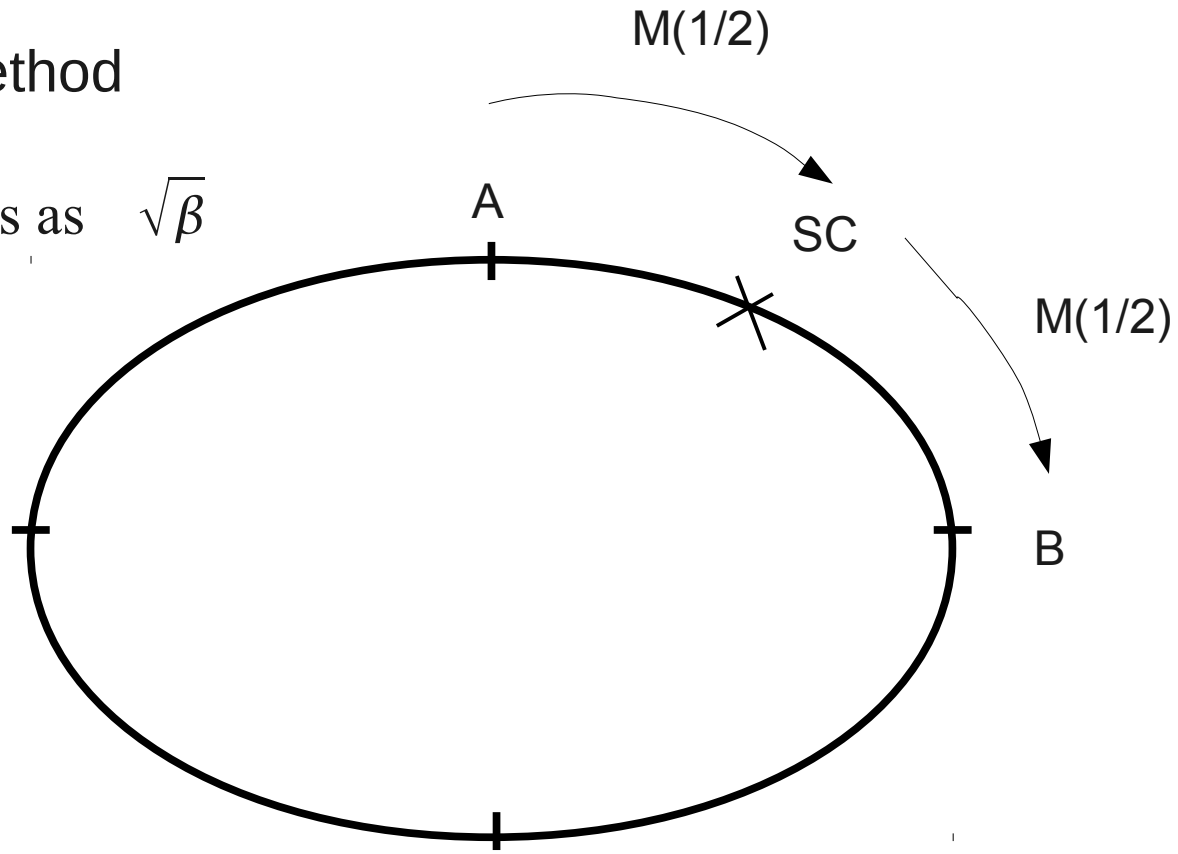
Linear maps for X and Y, sinusoidal RF for longitudinal

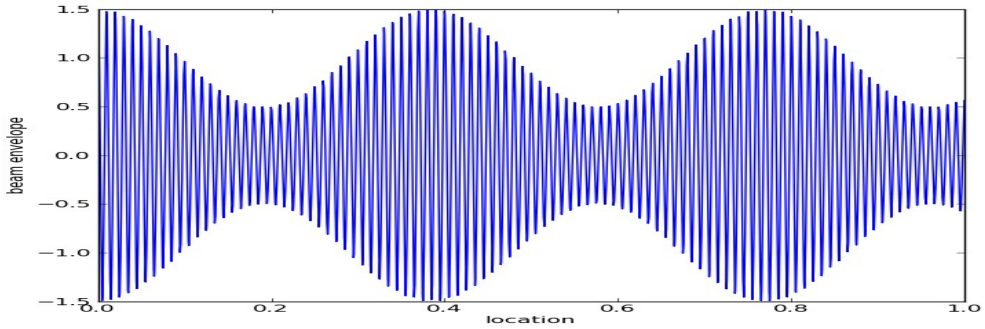


Determining how many space charge kicks

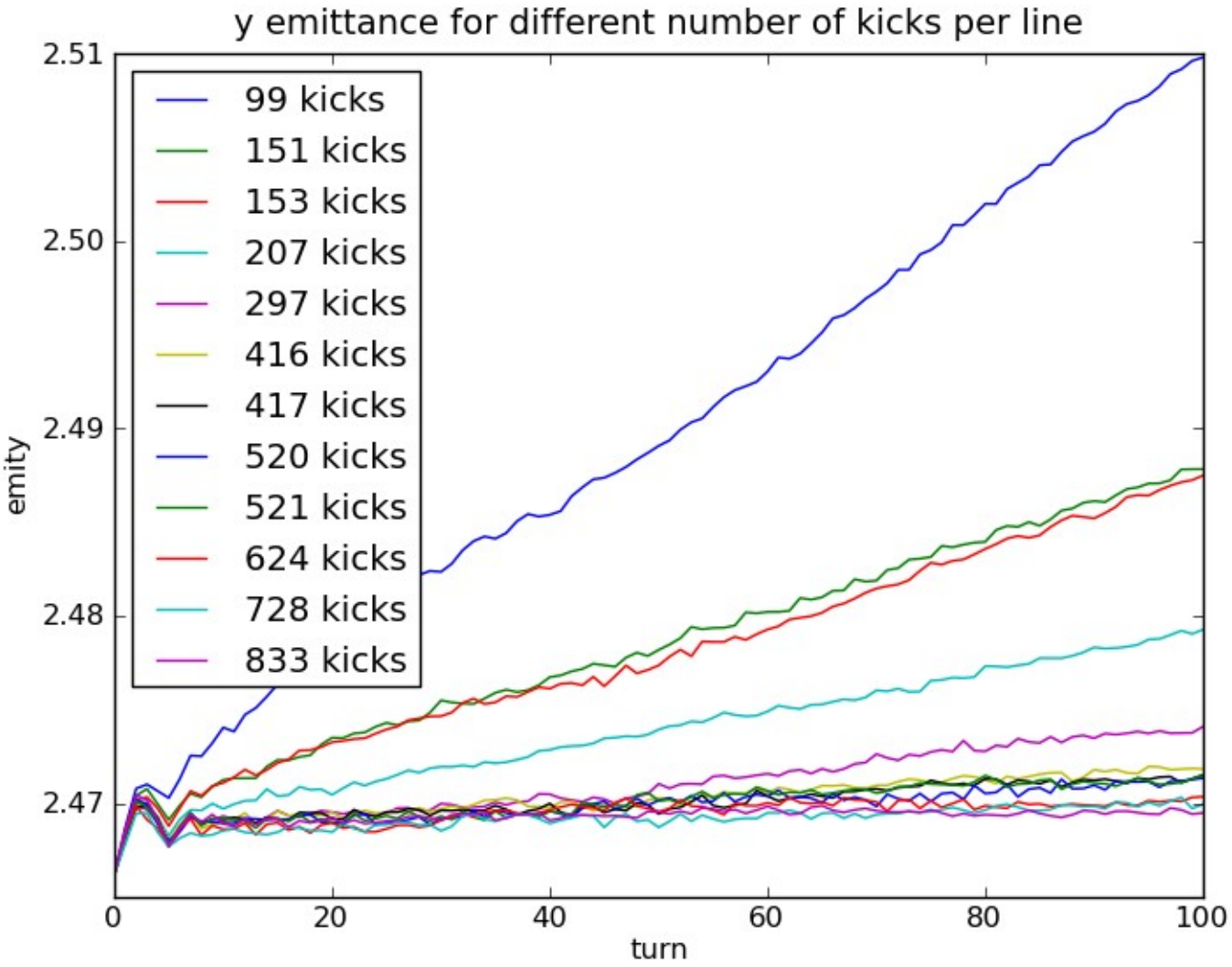
Split-Operator method

Beam Envelope varies as $\sqrt{\beta}$

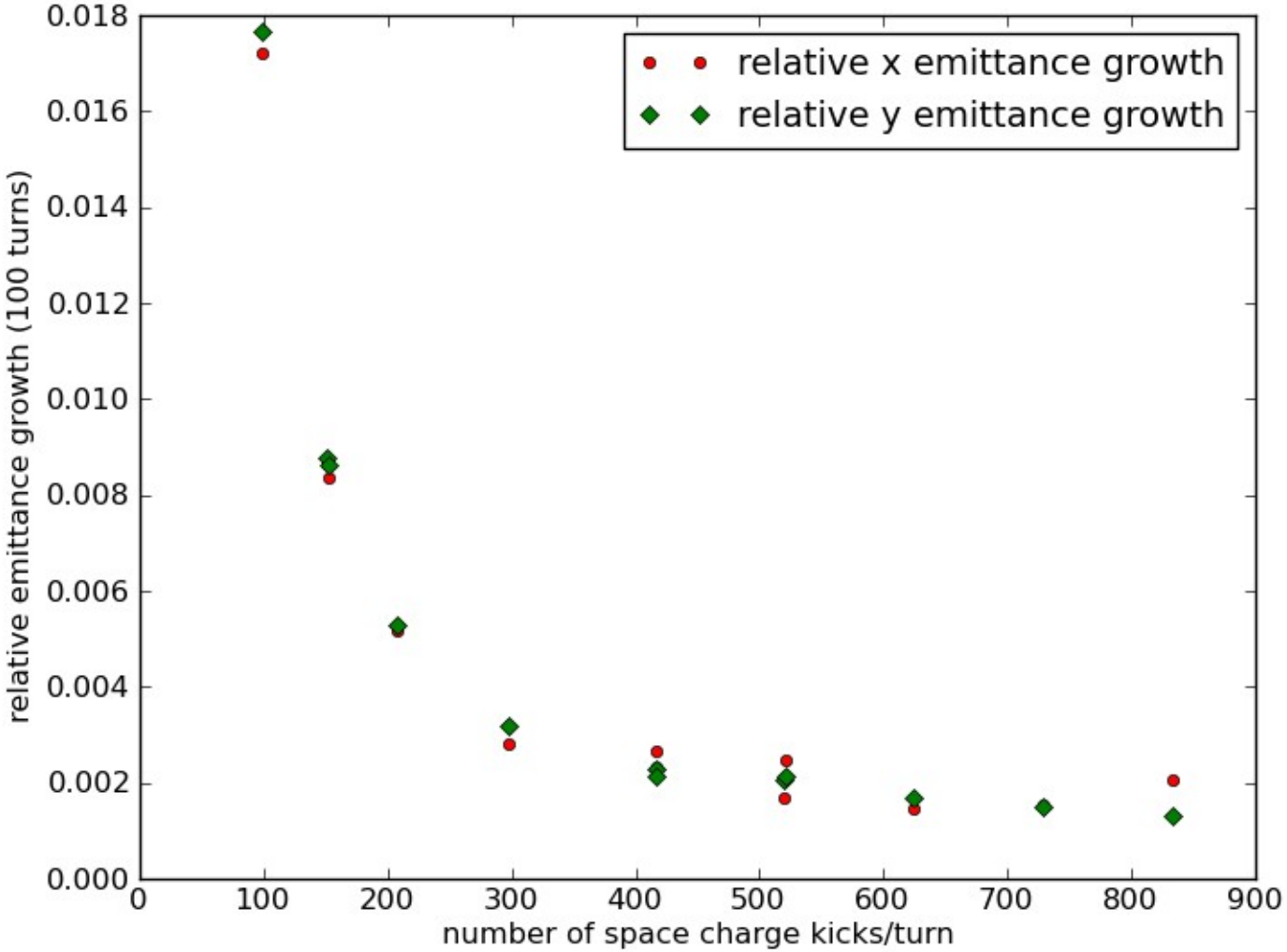




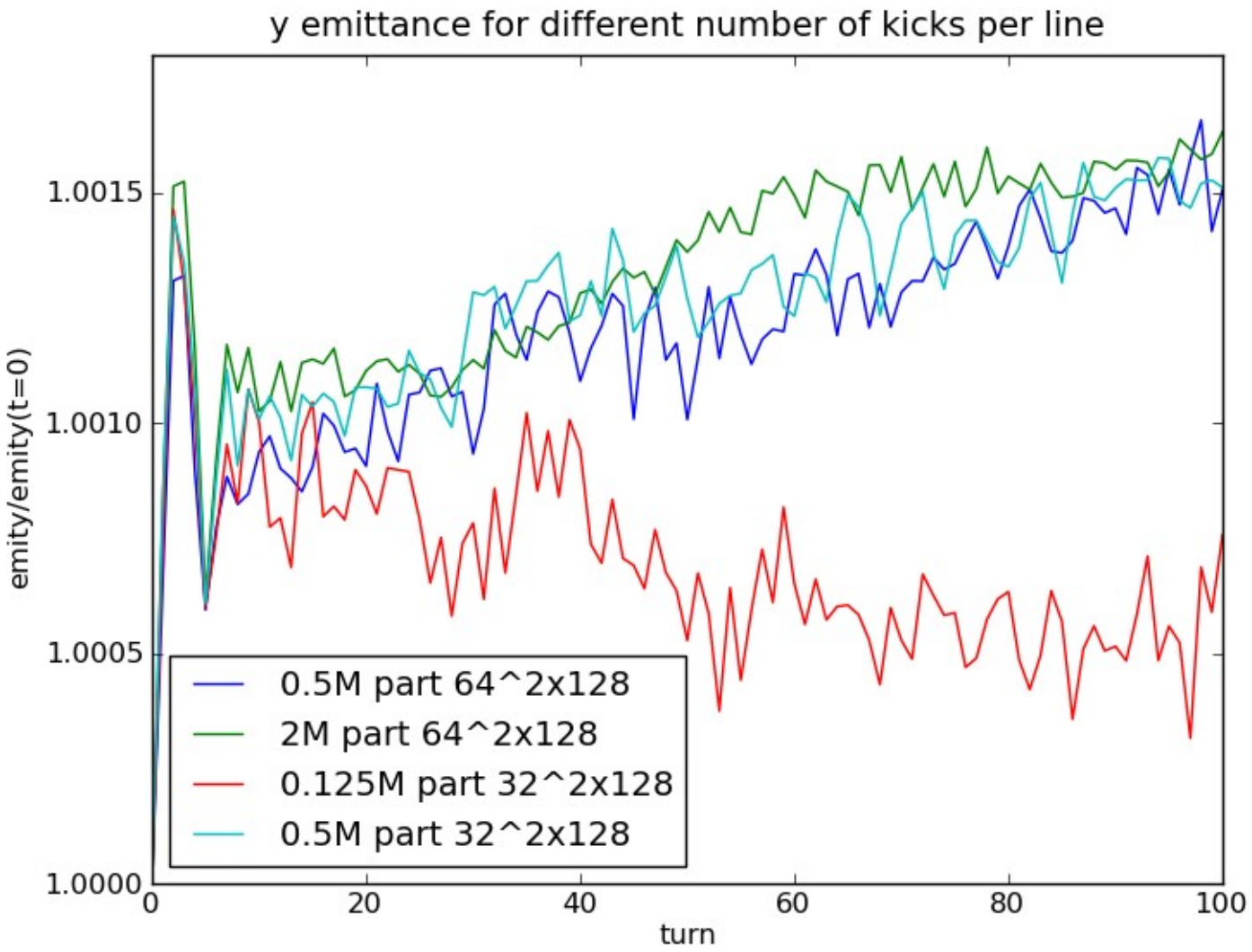
How many space charge kicks (continued)



How many space charge kicks (continued)



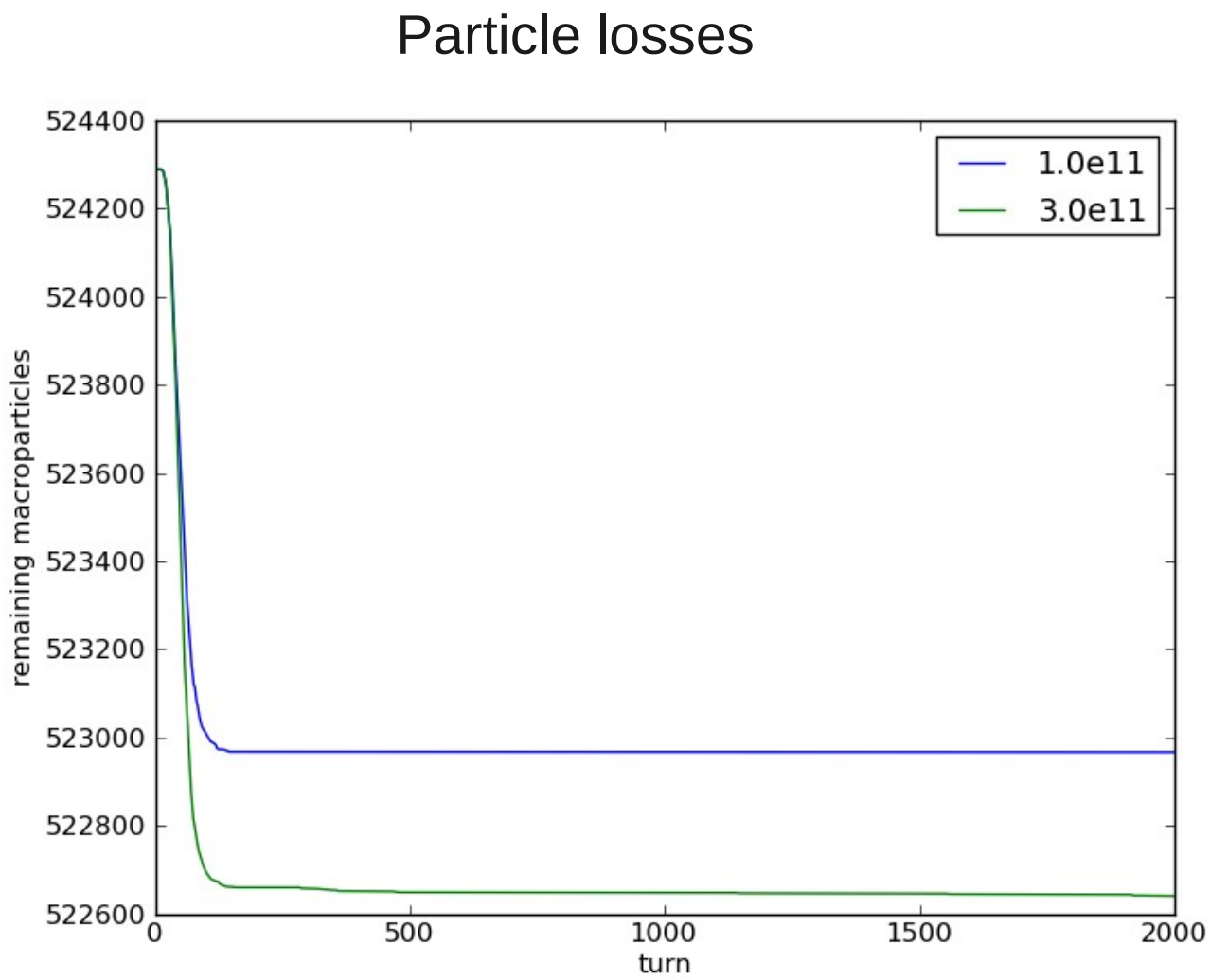
Grid size/macroparticle studies



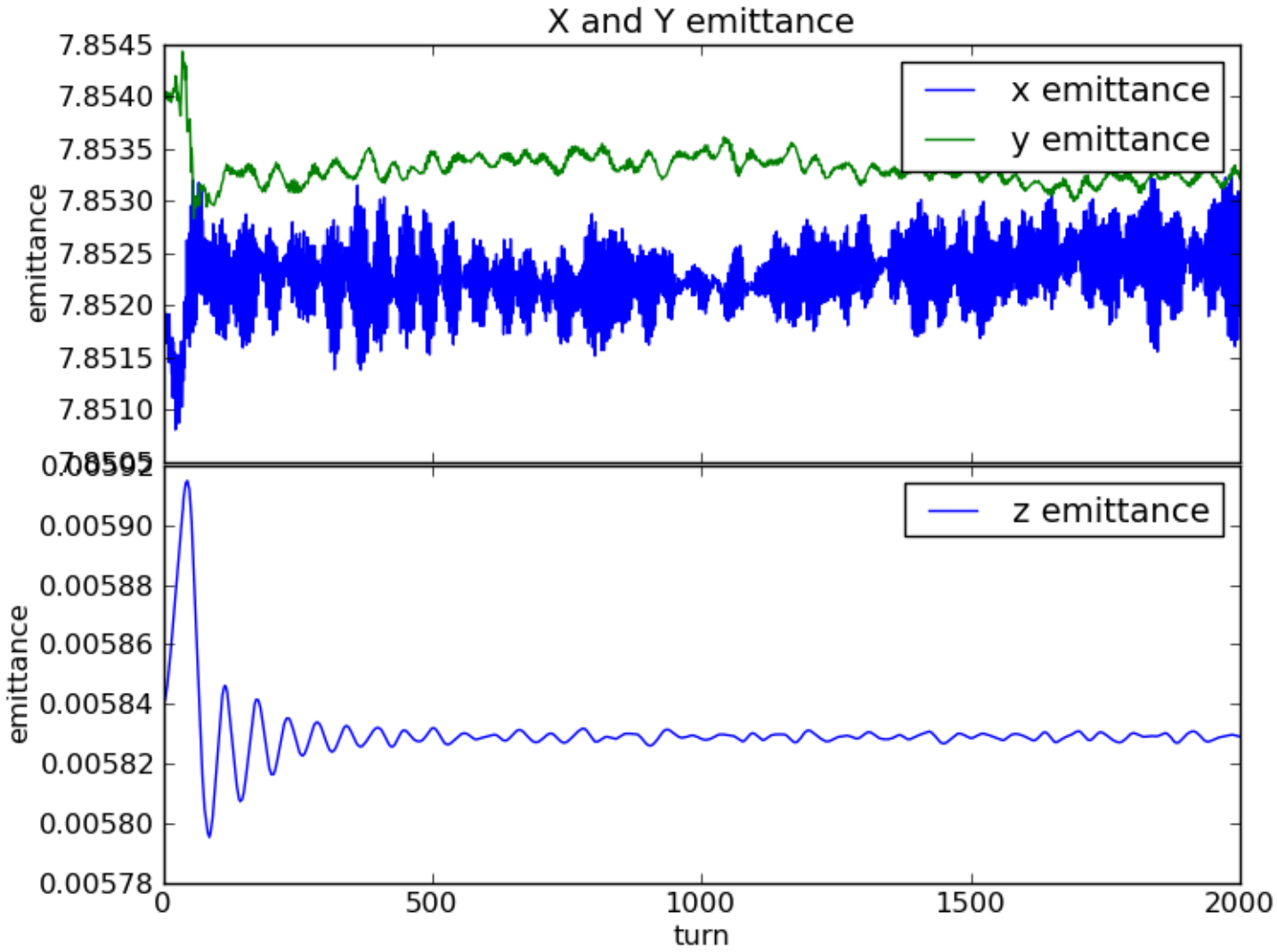
Compromise between running time and accuracy:

0.5M macroparticles, 32x32x128 grid

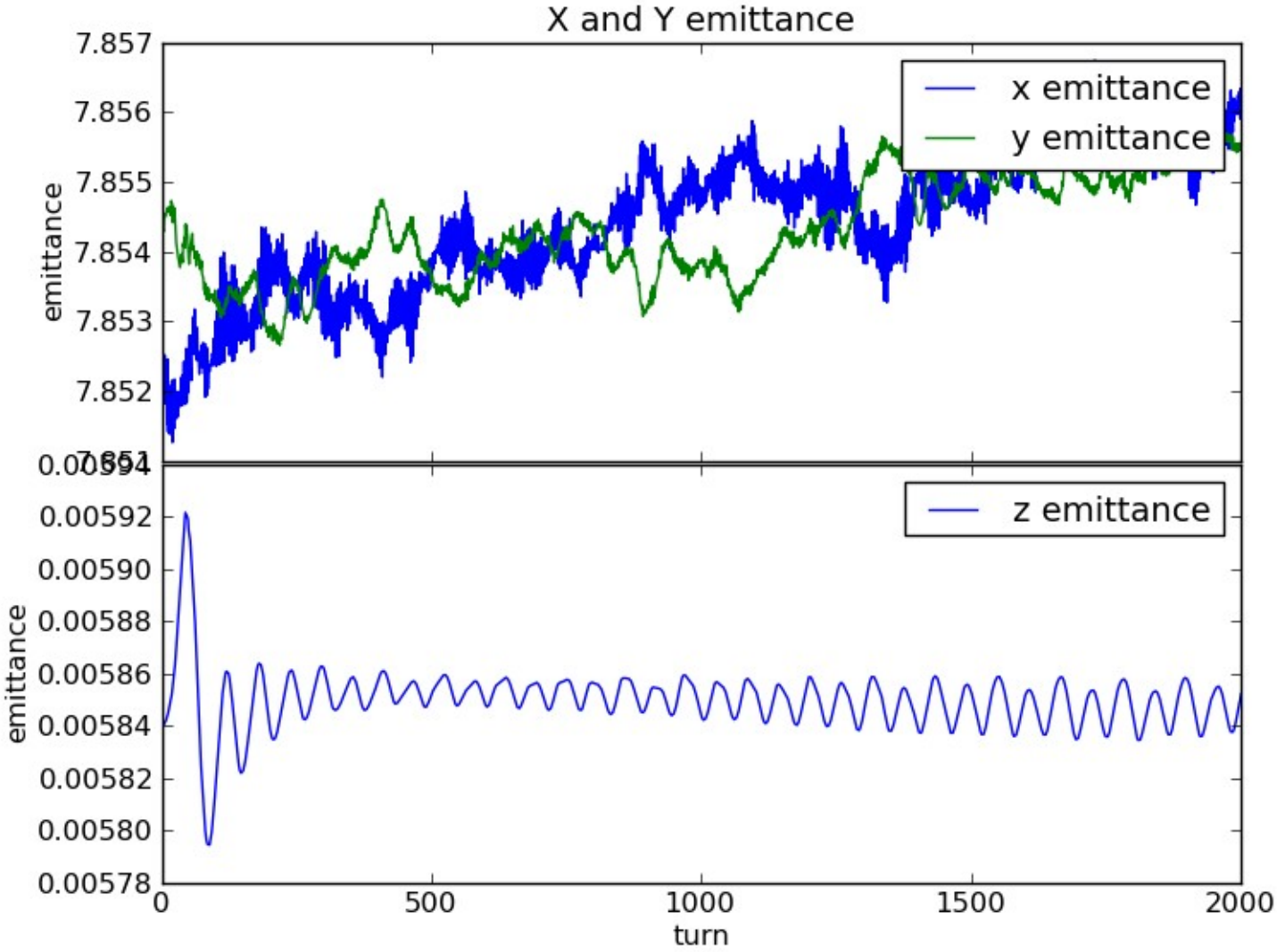
Run: 2000 turns 1.0e11 and 3.0e11 (Linear transverse maps, sinusoidal RF)



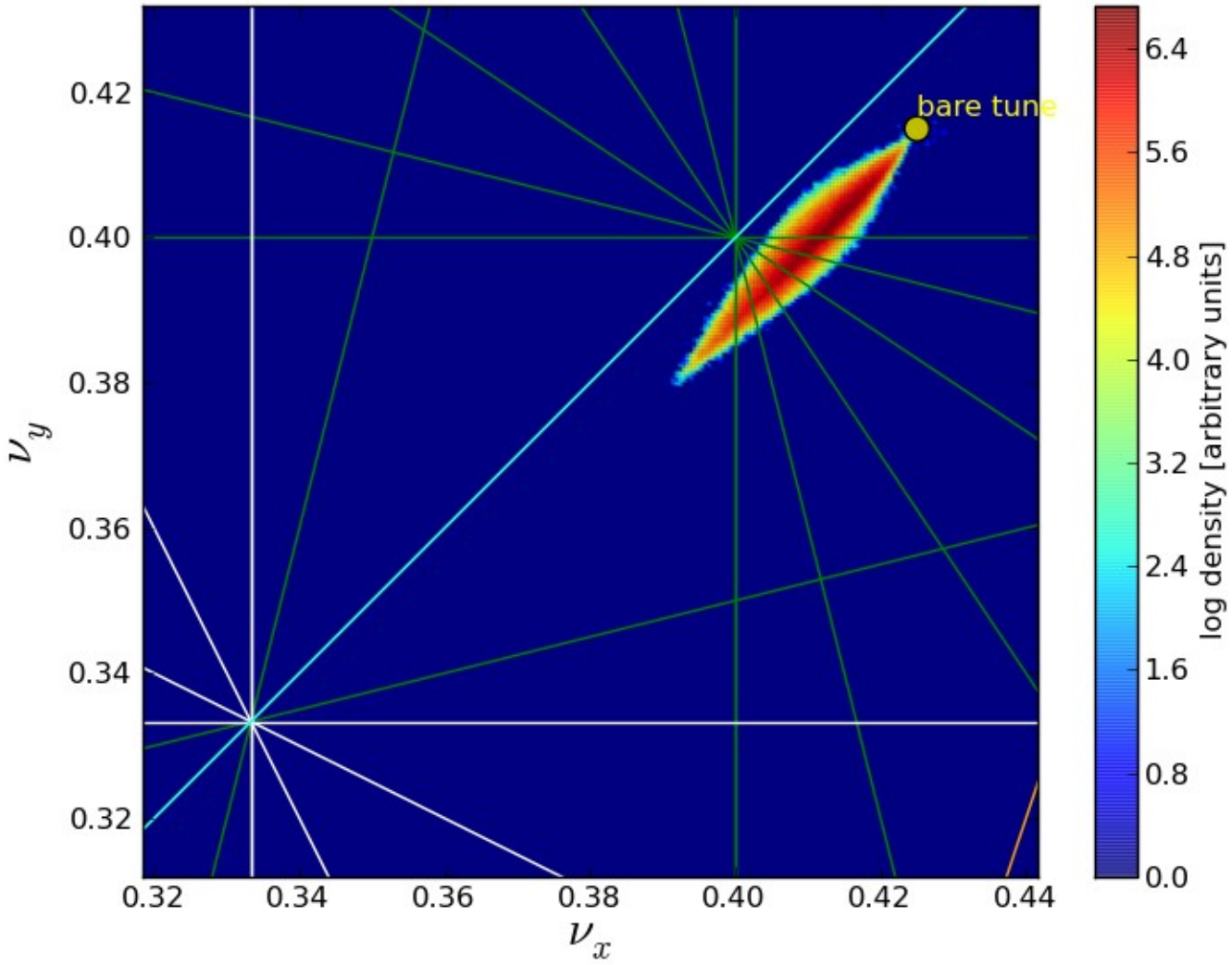
Emittances 2000 turns 1.0e11



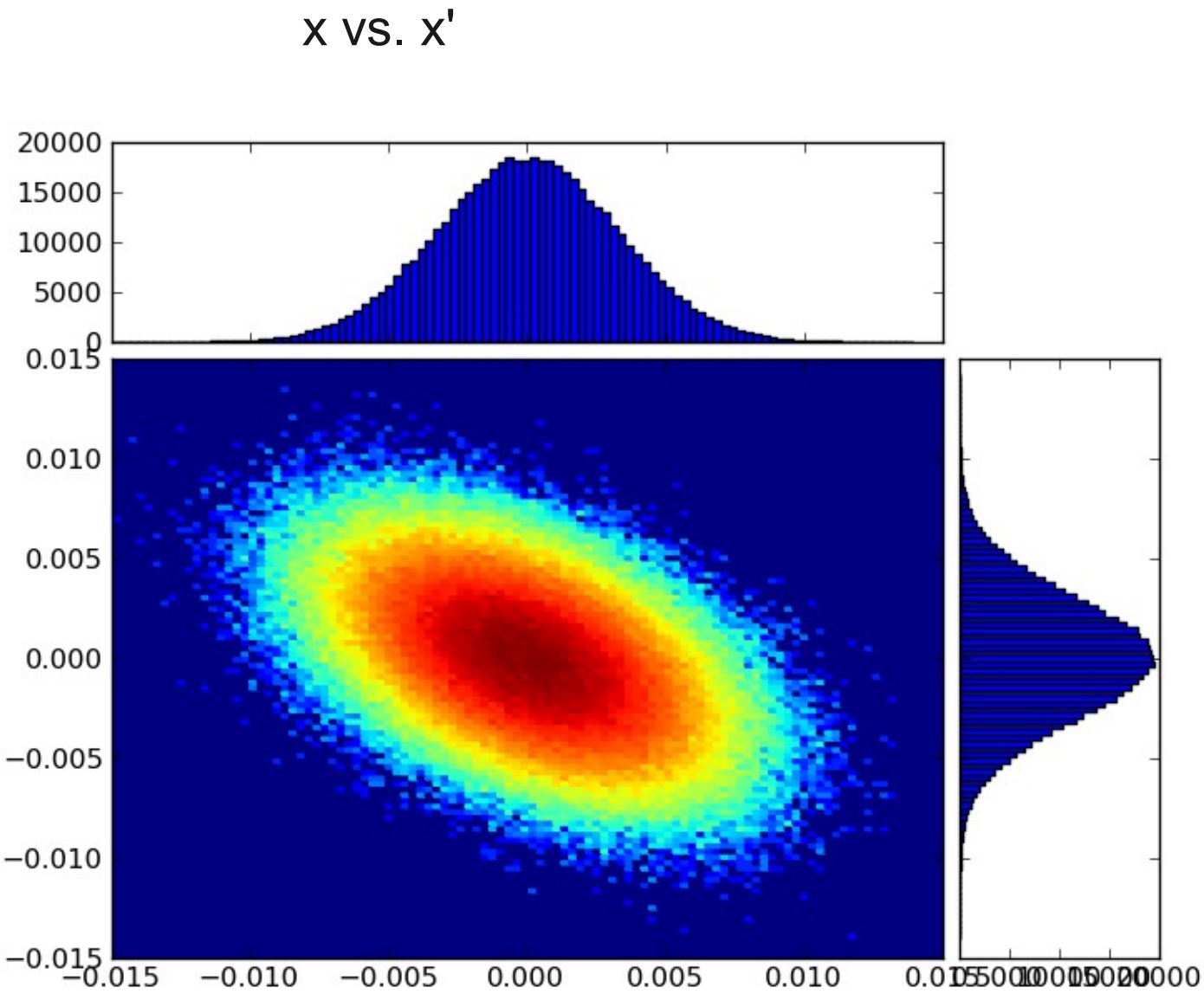
Emittances 2000 turns 3.0e11



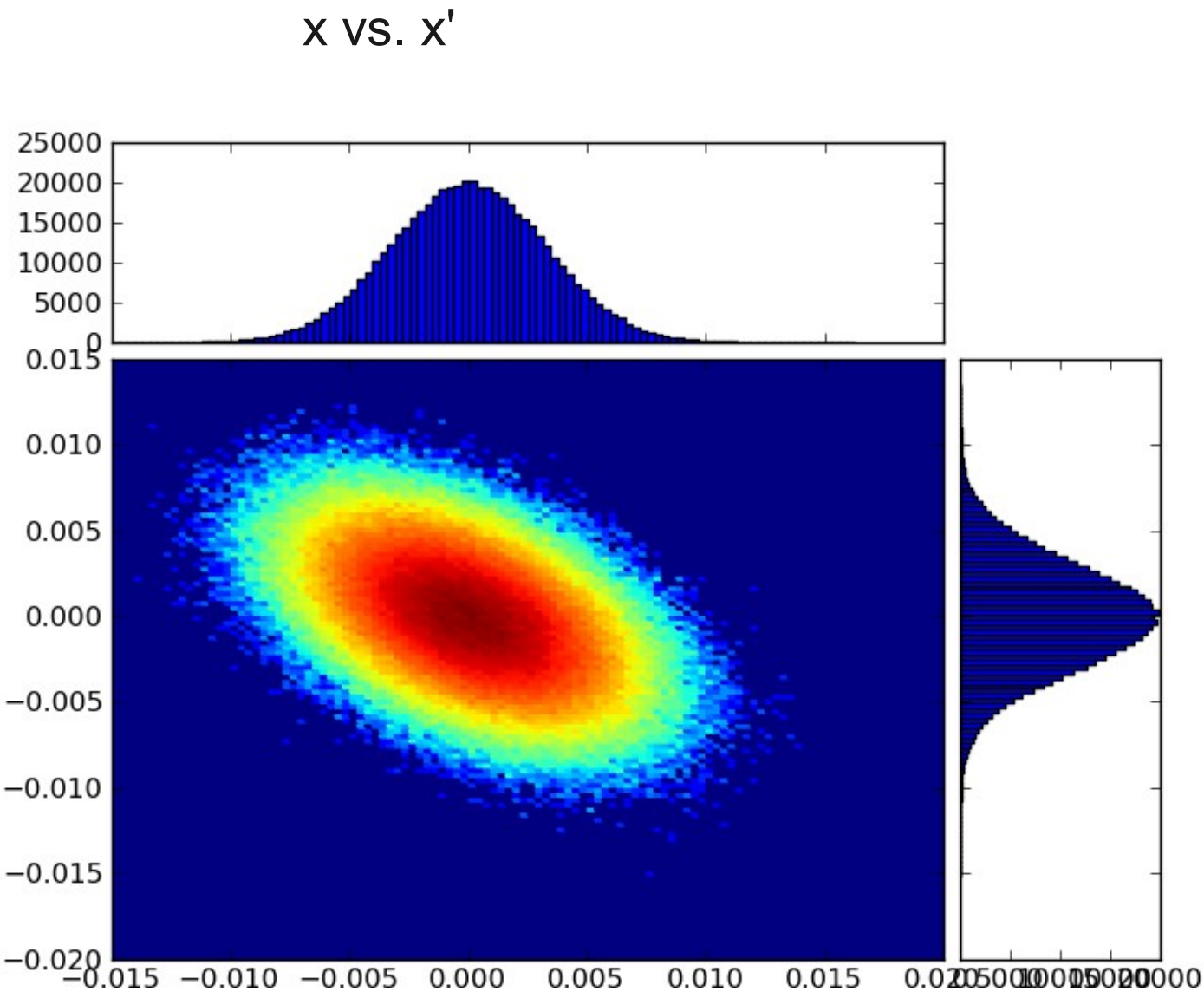
Tune footprint 2000 turns 1.0e11



Beam distribution 2000 turns 1.0e11

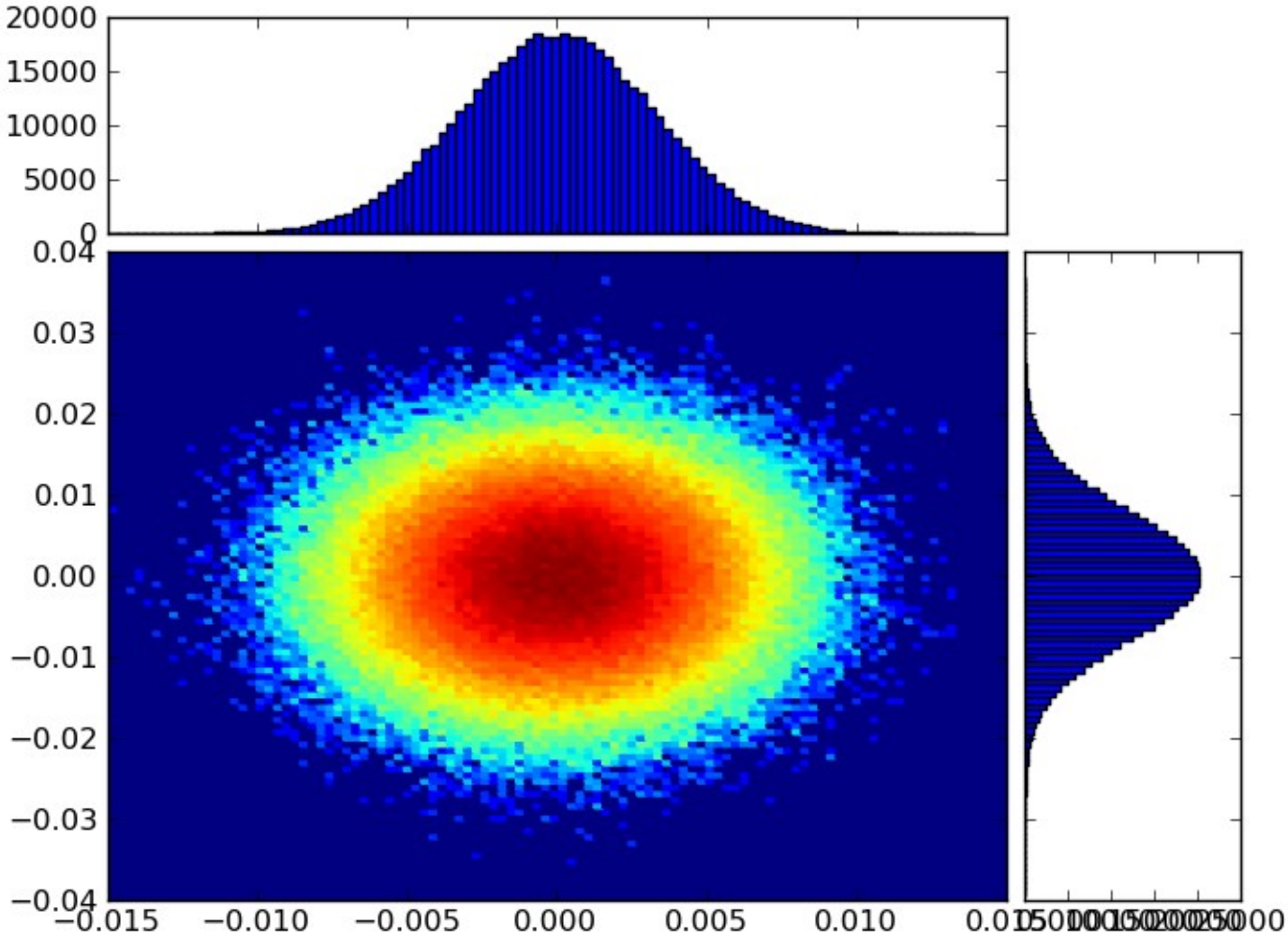


Beam distribution 2000 turns 3.0e11



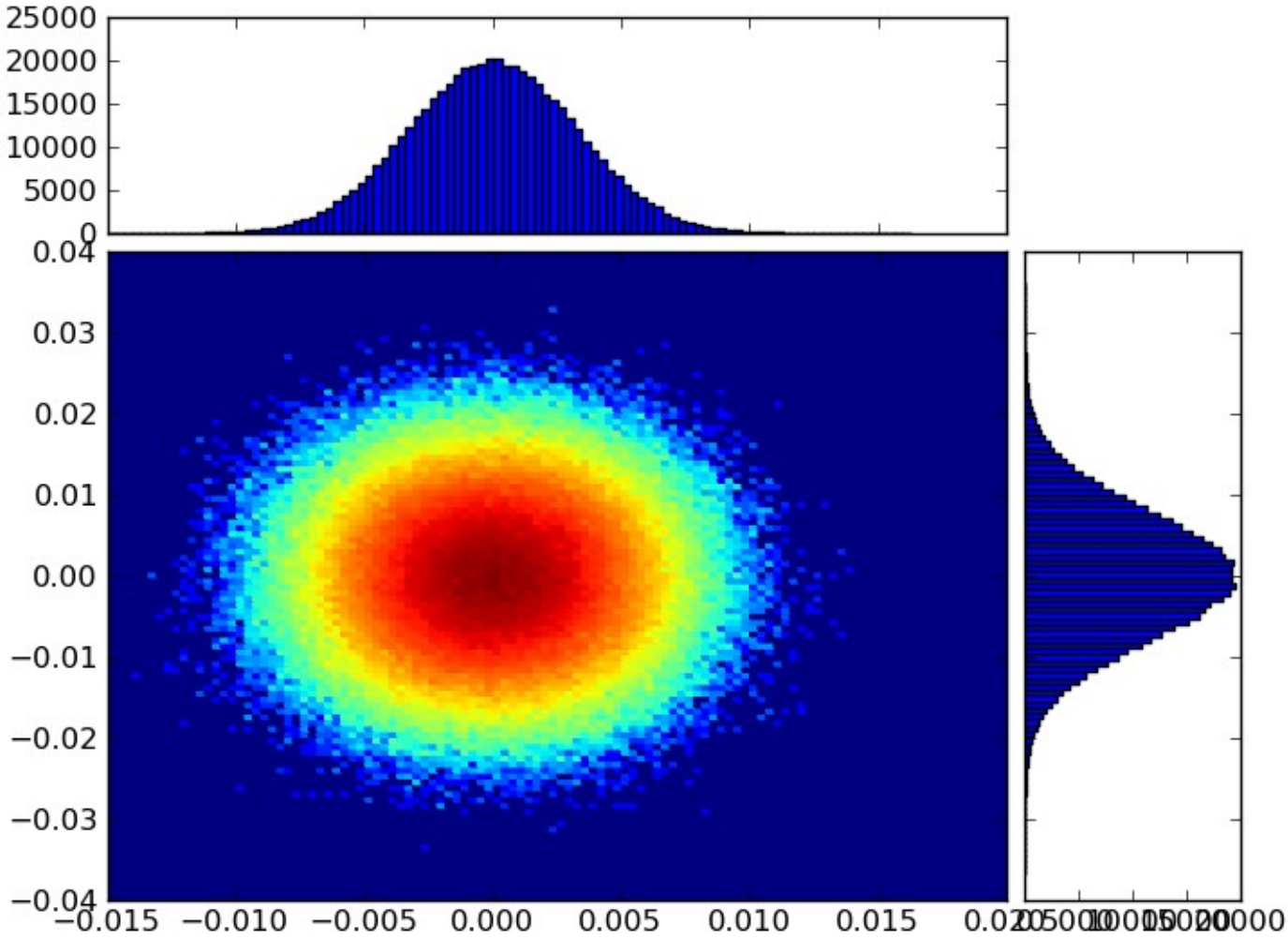
Beam distribution 2000 turns 1.0e11

x vs. y



Beam distribution 2000 turns 3.0e11

x vs. y



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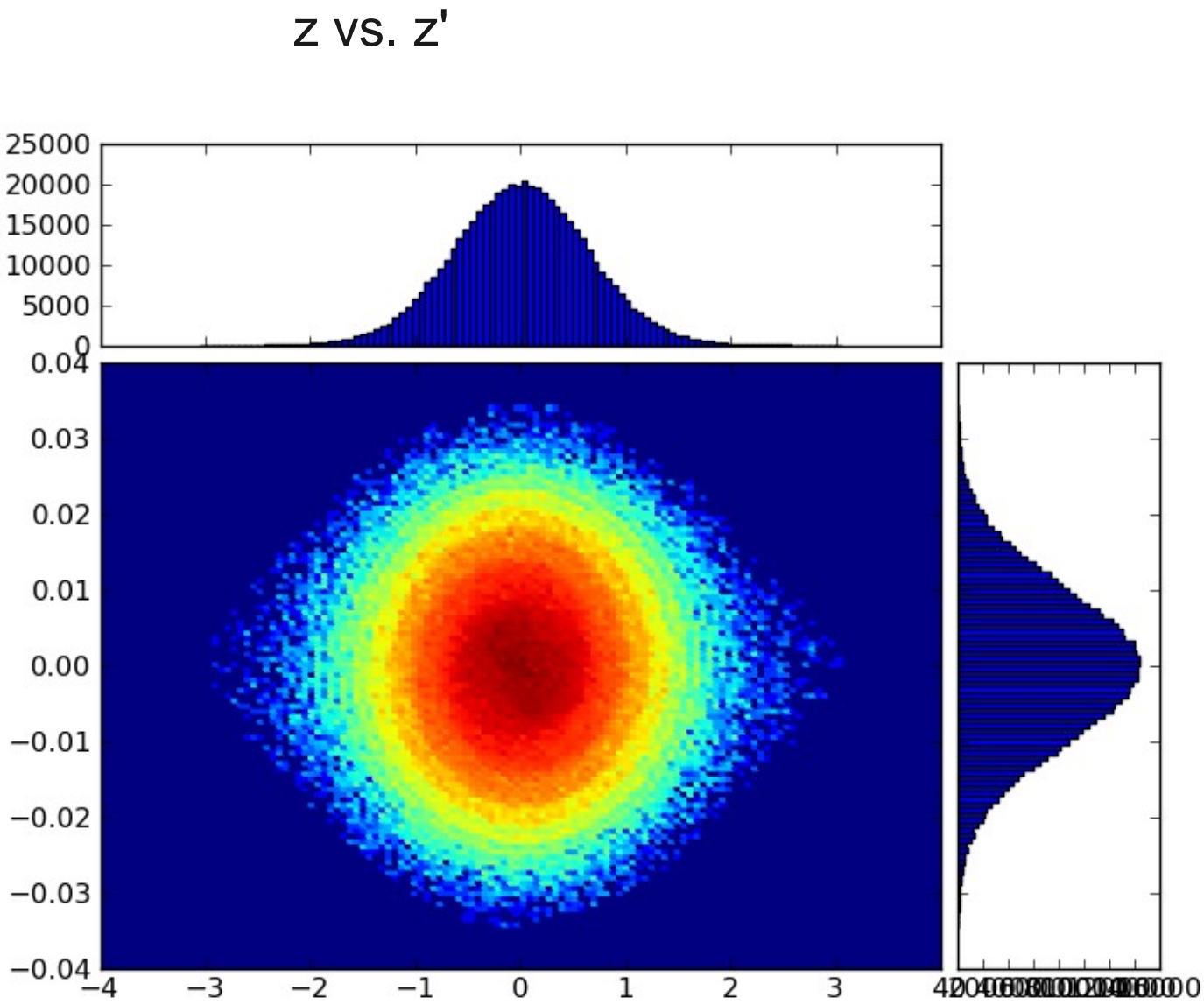

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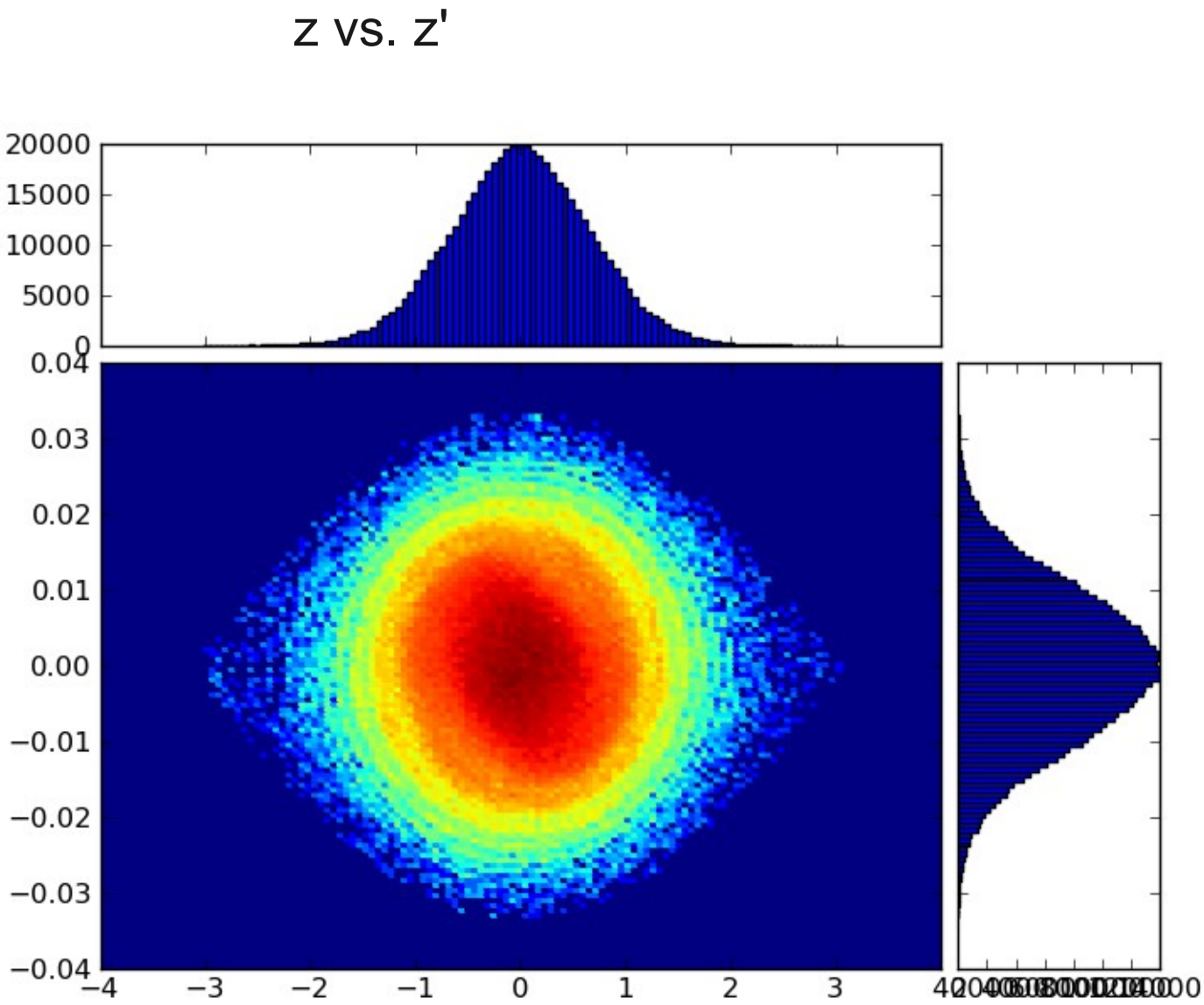

Future work

- Higher order maps
- Measured multipole moments
- Apertures
- Impedance
- …

Tune footprint 2000 turns 3.0e11